Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE FULL UTILIZATION OF THE CAPACITY OF THE MICROSCOPE AND MEANS FOR OBTAINING THE SAME.

EDWARD BAUSCH.

The cover glass may truly be called a necessary evil; for, while absolutely required in microscopical investigations, there is no adjunct to the microscope that has been and is productive of so much evil, and has retarded the utilization of benefits made possible by the advance in the construction of objectives so much as it. This fact was appreciated as early as 1837, when the angular apertures were what would now be considered extremely limited, and the appreciable effect of variations in thickness of cover glass was not then nearly so pronounced as it is at the present time, even in modern objectives of a narrow angle.

The accommodation for the different thickness was obtained by varying the distance between the systems of objectives, and has been followed with modifications in the mode of obtaining the necessary motion up to the present day. While open to some objection, it accomplishes the purpose quite satisfactorily and must continue to be used until something better is suggested.

One of the purposes of the homogeneous immersion is, as we know, the avoidance of the necessity of the cover correction, in that the cover glass immersion fluid and front of objectives are to be one homogeneous mass; but even under these conditions, which in practice were found to be not constant, it has been found advisable to provide cover-correction to obtain the highest possible results. However, even should this not be found necessary in the development of improvements in this class of objectives, it must be remembered that the majority of objectives will always be dry, and especially so when such improvements, which we hope are still to be made, are accomplished. It is an unfortunate circumstance that with this class of objectives the influence of variation in thickness of cover glasses is most apparent; but since it is so, we should, if possible, provide an agency which, eliminating the personal factor of efficiency, will give, under all conditions, results closely equal to those under which the objectives were originally corrected.

It is surprising to see how little attention is paid to this subject in the large majority of standard works on the microscope. Almost all books give carefully prepared illustrations and descriptions showing the effect on the course of light by the interposition of the cover glass, and after giving conclusive evidence of its disturbing influence, still, in a general way, say it is of little moment. Thus, in a German work of the highest standing, which has also been translated into the English language, is found the following utterance, freely translated:

"In regard to modern microscopes, which we have had opportunity to examine, we have not found the difference in thickness such as occurs in commercial cover glass, when, for instance, three to six are equal to a mm., has any noticeable influence on the microscopical image."

In another work of great popularity are found the following quotations: "That the effect of thickness of cover glass has a great influence on the perfection of the microscopical image is beyond the slightest question, and certainly deserves the most careful attention of the optician as well as the observer; but whether the devices of its removal are of such great importance and so absolutely necessary as it is claimed, is another question. On the other side, the difference in the cover glass used in different directions for the most delicate preparations is hardly of any account. I at least possess, besides my individual preparations covered with glass of about 1–5 mm. thickness, a collection of objects which I obtained from London and Paris, in which there is such a slight difference of cover-glass thickness that I can observe them all with my objectives of powers from 2.0 to 1.3 mm. (equivalent to about 1–12 to 1–20 inch) without showing the slightest difference in optical qualities and in the definition and clearness of the image under the same illumination, as I have convinced myself by careful comparative tests."

With such statements to guide the microscopists, it is not surprising that the subject should have received so little attention, and that any efforts to lead to improved methods of manipulating objectives should have almost completely failed because of a lack of the true understanding of their need and consequent failure to create interest. The belief is quite general that any time devoted to this subject is wasted and might better be utilized in other directions.

I hope to be able to show that this is entirely wrong, and may here say that, while I may be considered an extremist in the other direction, my efforts emanate from the desire to put it in the power of every microscopist to obtain the highest possible results from his optical battery and equal to those obtainable by the optician.

When in 1887 Prof. S. H. Gage addressed a circular letter to all opticians in the world inquiring for the dimensions of their standard tube length, as well as for the thickness of cover glass which they used as a standard in the correction of objectives, I looked forward to the result with considerable interest, as it would bring together data which it was impossible to obtain otherwise

At the meeting of this society in 1887, at Pittsburgh, he gave the results of his efforts, which show some astonishing facts. I would here say that while for a long time I had felt that a system that would permit the full utilization of the optical capacity of objectives of different makers under varying conditions of cover glasses was desirable, I was then forcibly impressed with the absolute necessity of a plan which would offer this advantage. Outside of the differences of the lengths of tubes used by different makers, which is also of great bearing on the spherical correction of objectives, one is astounded by the difference in standard cover glasses used by different makers in correcting non-adjustable objectives. With a thickness of 0.10 mm. for the thinnest and 0.25 mm. for the thickest, it is only too apparent that with the additional variation in lengths of tubes it is beyond the power of the microscopist to obtain even approximately the best results from his objectives. More than this, a large quota of the advance made in recent years in the capacity of objectives has been lost.

As Professor Gage states, "A uniform thickness for cover glass for non-adjustable objectives seems also desirable," and this would be the easiest solution of the question ; but while on the one hand the makers of objectives have not yet agreed to use one standard on account of the technical difficulties involved in departing from their established precedent, on the other the microscopist would hardly be willing to bear the expense which would be occasioned by the loss of cover glass not conforming to the standard in order to use those of one thickness. This expense might be greatly reduced by using selected covers of one standard on objects for all medium and high power objectives and the balance on all other preparations on which only low powers would be used, but this would of course be of little avail in face of the fact that manufacturers follow no standard.

The greatest difficulty is met with non-adjustable objectives. As is well known, compensation for thickness may be obtained in the proper adjustment of tube length; but while not all microscopes are suitably provided with draw-tubes, the requisite experience and skill is lacking with a large number of microscopists to properly make the correction in this manner, as well as in objectives specially provided with collar correction. I am sure that microscopists of long experience will bear me out in the statement that results with adjustable objectives depend upon individual skill, and that many such objectives now in use fail to give results corresponding to their capacity. It would seem, therefore, that any system to permit the full utilization of the capacity of objectives should depend on no personal factor—in fact, should be mechanical—and this I have followed out in the system I shall explain.

In an objective corrected for normal thickness of cover glass there will be spherical over-correction with thick covers and under-correction with thin covers, the amount of correction varying in a different ratio to the amount of variations from the normal thickness. The chromatic correction will also lose correspondingly, but to not so high a degree. While a deviation of a few hundred millimeters in either direction will, perhaps, not signify, that which occurs in covers classified in price-list under one number is sufficient to seriously affect and the high powers totally obliterate the definition which under normal conditions it may possess. The microscopist is therefore not obtaining such results as his objectives ought to enable him to obtain, and the efforts of the conscientious optician to provide classified objectives of reliability and similar performance is almost entirely nullified. In making the necessary experiments some astonishing results appear. With a non-adjustable dry 1–5 corrected for a cover glass of 0.16 mm., employing the extremes of cover glass which are used by the various manufacturers as standard, as obtained by the efforts of Prof. Gage, I found that for 0.25 mm. a tube length of 6 inches is required to obtain the proper correction, while for a thickness of 0.10 mm. 13 inches of tube length is necessary. In a 1–8 objective adjusted under the same conditions 4½ inches is the requisite for a cover of 0.25 mm., and for 0.10 mm. 15 inches. The further fact is shown that with a 1–5, which, under conditions of tube length and cover glass given above, shows certain structure, well defined, absolutely fails to show anything of it under a cover glass of 0.10 mm. on one side, and 0.25 mm. on the other, and further a marked chromatic over or under correction.

With a cover of 0.14, which would seem but a slight variation from the standard, the objective is spherically highly under-corrected, and with 0.18, highly over-corrected. With objectives of high power the difference is still more marked. For these experiments I have had Mr. J. D. Moeller, of Germany, mount a series of Pleurosigma angulatum dry and Amphipleura pellucida in balsam, under a series of covers varying from 0.10 mm. to 0.34 mm., each carefully measured and marked. I have used these objects because they are my favorite tests, and it goes without argument in saying that any preparation showing structure under above objectives will be affected to the same extent by the varying conditions of cover glass, as these objects and in objects of still finer structure the limit of visibility will be reached correspondingly sooner.

The system which I have devised to aid in overcoming these difficulties depends in the first instance upon a micrometer for measuring the thickness of cover glass. While the delicate instruments made by M. Grossman, of Germany, are excellently suited for this purpose, they are expensive. I have endeavored to overcome this objection by constructing a plain screw which, while not so sensitive to the touch, is sufficiently so for all practical purposes. The instrument is provided with a stand of japanned iron. Cut horizontally through the top is a thread of $\frac{1}{50}$-inch pitch and $\frac{3}{16}$-inch outside diameter. A recess is cut on the top below the line of the screw and at right angles to it for placing the covers. The one-half of the top of the stand which receives the micrometer screw is slotted longitudinally to the depth of the screw and is provided with a set-screw to take up wear. The other half has the fixed screw, adjustable, however, for final adjustment. The end of the micrometer screw is milled, but of a small diameter, so that no force can be exerted so as to endanger the cover glass. Fixed on the screw between two nuts is a brass drum with a ½-inch face. A knife-edge index finger is fixed to the top of the stand and projects over the top of the drum. To the outside diameter of the drum is fixed a strip of glazed paper provided with a series of divisions. The first gives the thickness of cover glass in one-thousandth inches, the second one-hundredth millimeter. The third indicates the proper tube length with various thickness of cover glass with a non-adjustable ¼ corrected under a tube length of 8½ inches and cover thickness of 0.16 mm.; the fourth gives the tube lengths of a 1-5 inch objective under the same conditions; the fifth for a ⅛, and the sixth for a 1-12 for same conditions of tube length and cover;

the seventh is for a 1/6 with the same cover and tube length of 160.0 mm.

In objectives provided with cover correction the graduation is so arranged as to read to 1–100 mm. No matter what the power of objective or whether dry or water immersion, the number gives proper correction for a thickness corresponding to it. Thus, with a cover glass of 0.20 mm. the collar of such an objective need merely to be set at 20 to give the proper correction and, consequently, the best results. On the other hand, with an objective which is graduated on this system the correct thickness of cover glasses can be determined by obtaining the proper correction on preparations previously made, but on which the thickness of cover glass is not noted and the thickness may be marked on them for future convenience. To do this successfully, however, the necessary experience is requisite. All the other scales give the correct tube length in inches and millimeter for covers corresponding to them, and in this manner offer a ready and definite means of correction. The tube lengths required for the thinnest and thickest covers are so extreme that probably no convenient means for obtaining them can be practically arranged, but they can be so approximately if not entirely. At any rate, the micrometer will detect the requirements before using the covers, and those deviating considerably from the normal can be used on objects for use with low powers only, in which case the effect will not be very appreciable.

In this system I do not overlook the fact that variation in tube length involves a variation in magnifying power; but, except in cases when micrometers are used, I consider this of secondary importance, as it always is in comparison to results obtained in resolving and defining power.

This system involves four conditions:

First. That all cover glass be measured before using them, and that the thickness be noted on the preparation.

Second. That for convenience all draw-tubes be marked in inches or millimeters or both.

Third. That adjustable objectives be corrected according to this scale.

Fourth. That the same tube length and cover glass thickness be used in all original corrections of objectives.

As regards the first condition, there are many microscopists now who measure all their covers before using them; but the mere knowledge of thickness has been of no value up to the present time, because this in itself has been no guide in obtaining better results except by approximation. My aim in connection with this system has been to devise an instrument which possesses a high degree of accuracy and still be so inexpensive that its price should be no obstacle to its general use.

The celebrated preparer of objects, Mr. J. D. Moeller, and others have kindly agreed to mark the thickness of covers in their objects so as to aid the introduction of this system, and other preparers can no doubt be induced to do so if its advantages can be proven.

As regards the second point, many manufacturers now graduate their tubes, and modern requirements demand that this should be more generally done. Our company intends, as soon as it can possibly arrange to do so, to graduate the tubes of all its instruments.

As to the third and fourth conditions, I cannot, of course, presume to ask manufacturers to adapt their standards to this system. While it will be a convenience to a large number of microscopists, I must leave it to the merits this system may possess to exert their influence in this direction.